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Resilient Infrastructure as a Tool for Flood Risk Management in Nigeria: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Flooding is a disaster which may occur naturally or as an effect of human activities. Flooding which is a global hazard has resulted in devastating effects on humans and the environment. Thousands of lives are lost and properties worth several millions of dollars are destroyed annually due to flooding in Nigeria. Various Flood Risk Management (FRM) approaches have been employed to manage this menace in Nigeria resulting in little success. This paper highlights the types, causes and impact of flooding in Nigeria as well as evaluate the efforts at local and national levels in FRM. After due considerations of performance and lapses of past efforts, the article advances the resilient infrastructure approach as a formidable and sustainable FRM option for Nigeria.

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1. INTRODUCTION

Nigeria has a climate that ranges from semi-arid to humid from the north to the south, characterized by distinct wet and dry seasons, and the rainy season duration that varies between 3 to 10 months from the north to the south. Nigeria has an estimated mean annual rainfall of 1,150 mm. Almost the whole country is exposed to natural hazard events. Communities along the major drainage basins and their tributaries are mostly affected by floods while flash floods impact any region that experiences extreme rainfall [1].

With the soaring national population and the need for shelter, the availability of land for building and infrastructure is becoming a matter of great concern in urban areas. According to the World Cities Report (2016), about 1 billion houses will be needed worldwide by year 2025. It also states that 30% of the urban population in developing countries reside in slums. Nigeria has an annual population growth rate of 2.5%, with a rapid urban population growth rate of 4.5% and slow rural population growth rate of 1.4% indicating a high rate of rural-urban migration. Nigeria's rapidly increasing urbanization has resulted in the enlargement of the landscape of flood prone communities and assets [2-6].

The International Code Council [7] defines "flooding as a general or temporary condition of partial or complete inundation of normally dry land from the overflow of inland or tidal waters, or the unusual and rapid accumulation or runoff of surface water from any source". Flooding is a disaster that usually occurs naturally or as caused by human activities, resulting in harm to humans and the environment. Flooding is one environmental problem that occurs regionally, nationally and globally. It occurs in various ways and conditions such as changes in atmospheric conditions, rainfall variations, continental drift, moderate to severe winds over water, climate change, tsunamis, failures of dams, or other infrastructure that retains surface water can influence the occurrence of flood.

In this paper, the types, causes and impact of flooding in Nigeria is investigated. The performance and lapses of past Flood Risk Management (FRM) approaches in Nigeria is also evaluated. The article further advances the resilient infrastructure approach as a formidable and sustainable FRM option for Nigeria.

2. CAUSES AND IMPACT OF FLOODING IN NIGERIA

Nigeria's flooding is majorly attributed to anthropogenic factors. Several human activities such as deforestation, indiscriminate dumping of refuse in drains, unregulated urbanization, inadequate to non-existent environmental infrastructure, weakness in institutional capacity and coordination, early warning systems and public awareness, weak implementation of planning laws and corruption have been observed to cause flooding in Nigeria [8-11]. The Nigeria Hydrological Services Agency [12] attributes the causes of recent flooding disasters in Nigeria to the soil moisture regime of lower plains at the peak of rainy seasons, extreme weather conditions due to climate change, dam releases by bordering countries, topography, inadequate drainage systems in urban areas, clogging of river channels with wastes, deforestation, obstruction of drainage channels, poor waste management, rapid urbanization, poor compliance with or unavailability of spatial plans/building codes, and climate change.

Disasters usually result in much pain and huge economic losses and, in most cases, quantifying the cost of damages and recovery is difficult [13]. Flooding across the globe has resulted in massive loss of lives as well as huge socio-economic losses. According to the Global Facility for Disaster Risk Reduction (GFDRR), in the past 20 years, natural disasters have impacted 4.4 billion people, resulted in the loss of 1.3 million lives, and caused economic losses of $2 trillion across the globe. It also states that, over 80 percent of the total lives lost to disasters in the last 30 years are from low- and middle-income countries, leading to huge setbacks of national economies by 5 to 120 percent of their gross domestic product (GDP). It further states that the impact of disasters on GDP is 20 times higher in developing countries than in developed/industrial nations. Future losses are expected to increase in the built environment as the scale, frequency, and severity of natural hazards continue to rise. By 2030, the annual losses from natural disasters is expected to increase from about $300 billion to $415 billion [3].

Flooding in Nigeria has resulted in enormous devastation both to lives and properties, with the 2012 and 2022 flooding events been the most devastating in recent history. Accurate data on the impacts of flooding in Nigeria are inconsistent as the flooding impacts are poorly documented [11]. "In Nigeria more people are affected and displaced by flooding than by any other disaster; it also causes more damage to properties. At least, 20 per cent of Nigeria's population is at risk of flooding" [14]. The Centre for Human Security of the Olusegun Obasanjo Presidential Library Foundation [15] and the UN Office for the Coordination of Humanitarian Affairs [16] in their 2012 flood reports revealed that the 2012 floods in Nigeria resulted in the displacement of 2.3 million people from their homes; 363 human lives were lost; 16 million people in 108 local government areas were adversely affected; 600 000 houses damaged and the total estimated losses of from the flood as N2.6 trillion or $16.9 billion. The 2022 flood affected 34 out of 36 states in Nigeria, impacted over 2.8 million peoples, with over 1.3 million people displaced, over 600 lives lost and over 200 000 houses partially or totally damaged [17,18].

Flooding is the most wide-reaching disaster in Nigeria, and is a threat to Nigeria's achievement of the sustainable development goals (SDGs) as there is an increased vulnerability of populations and infrastructure to flooding and flood related hazards. Reducing disaster risk is therefore central to achieving sustainable development especially in developing countries like Nigeria [13,19,20].

3. FLOOD RISK MANAGEMENT IN NIGERIA

"Flooding like other natural disasters cannot be eradicated; they can only be managed. FRM strategies are aimed at the reduction of the likelihood and impact of floods. These strategies encompass predicting flood hazards, socio-economic factors and consequences, and measures/tools for risk reduction" [6,10,1]. The effective prevention and management of disaster situations (such as flooding) and ensuring sustainable regional development have been a source of major concern of the relevant stakeholders in disaster risk management. Meanwhile, because the meantime interval between floods can be irregular and not easy to predict, the lessons of the 'last' flood disaster tend to be forgotten by these stakeholders as they become relaxed until another flood strikes [13,6].

Even though Nigeria is signatory to various agreements and protocols such as the SDGs and Sendai Framework, most of Nigeria's FRM efforts have been reactionary and short-term post-hazard measures such as relief materials distributions, erection of internal displaced peoples' camps. Disaster management in Nigeria is still at infancy stage. The lack of relevant legal and policy frameworks by all levels of government in Nigeria is an indication of the low importance given to the control and management of flooding in Nigeria [20,13,10].

"Various interventions have been done in the past, but integrated and sustainable FRM systems and practices in Nigeria is still lacking. Piecemeal responses mainly focusing on alleviating immediate and short-term needs such as rebuilding of destroyed assets have been given to the past flooding events. With the enormous resources and investment been put into some structural FRM measures, the adaptation of these technologies to the Nigerian socio-technical environment has been a limited, and there is the absence of the required knowledge transfers to Nigerian experts" [6,21].

"The absence of a national FRM strategy indicates that little attention is paid to Nigeria's flooding challenge. The current FRM practices in Nigeria is characterized by the lack of inter-agency coordination, absence of holistic or system thinking in urban system planning and development, inadequate drainage network, high urban poverty, substandard and weak infrastructures, low level literacy, weak institutions, the disconnection between FRM systems and other subsystems of the built environment, and cultural barriers. The design and implementation of adequate FRM strategies involving proper spatial planning and infrastructure would in no small way help in controlling the floods. This can be done through a coordinated and committed participation of relevant stakeholders making use of appropriate regulations as key guide and document for quality management" [6,10,22].

"In most Nigerian urban centres, a disconnection exists between FRM systems and other elements of the urbanization process; there is need to strengthen risk reduction and mitigation capacity. Some of the challenges in reducing and mitigating flood risk include inadequate flood

control infrastructure, lack of flood risk awareness, inadequate dam monitoring and maintenance, aging or weak dams, inadequate solid waste, sewage, drainage, and flood zone management. Urban areas require special consideration, with integrated flood risk management, planning, and enforcement. Many cities or small towns are vulnerable to flood risk, and priority needs to be given to the preparation and implementation of structural and nonstructural flood control measures" [6,1].

"The main focus in tackling flood risk in Nigeria has been on structural measures coupled with over dependence on nonindigenous expertise and technologies. The adoption of cost-effective strategies that focus on flood management and the integration of the concept of living with floods, protecting key assets, and minimizing losses can strengthen Nigeria's FRM and protect human lives, as well as properties and infrastructure. Nigeria has poor flood warning systems as well as a poor flood insurance scheme. Hence, building resilience capability to cope with increasing climate variability remains the most viable option for FRM in Nigeria" [6,10,1].

Countries across the globe have recognized the need to formulate clear regulatory policies aimed at preventing, managing and reducing disasters. A number of steps have been taken in the right direction which would boost their capacities to confront most natural disasters. An integrated and holistic approach to development in which flood management is given a high priority is the only sustainable approach to FRM in Nigeria. This approach to development will require a high level of inter-agency coordination and integration. Inter-agency coordination and integration, vis-a-vis FRM, will allow for the interrelations exiting among urbanization processes and systems to be systematically explored and exploited in a complimentary manner. A good proactive approach such as the resilient infrastructure system would strengthen flood mitigation in Nigeria. "This approach will identify ways in which exposed communities can better anticipate, mitigate, prepare for and cope with the occurrence of present and future hazard events. The resilient infrastructure approach would enable the system to absorb hazard disturbances, learn from mistakes in past responses, reorganize after disturbance events, and prepare for possible future shocks and anticipated impacts, thus, managing hazards instead of merely controlling them" [13,6,23].

4. THE NEED FOR RESILIENT INFRASTRUCTURE IN NIGERIA

"Resilient construction has been practiced for centuries, but only recently gained relative adoption as a systematic component of an integrated FRM strategy. Resilient buildings are designed and constructed in such a way to avoid, prevent, or reduce the damage caused when flooding takes place. They can play an important part in FRM strategy by reducing damage and, speed up the recovery process" [24]. Holling [25] first introduced the concept of resilience as "the ability of an ecological system to absorb and recover from external shocks." However, the widely accepted UN definition for resilience is: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" [26].

"The context of the resilience of development interventions and the resilience of infrastructure could be considered as both in terms of the resilience of infrastructure itself, and how infrastructure affects resilience: both of other infrastructure systems, and of individuals, households and communities" [27]. Resilient infrastructure is about the people, the households and communities for whom infrastructure is a lifeline to better health, better education, and a better livelihood. It affects people's well-being, their economic prospects, and their quality of life. Resilience is important to both developed and developing countries, as disaster and climate impacts are not influenced by a country's Gross Domestic Product (GDP), and risks apply to both existing and new infrastructures. Infrastructure disruptions are an everyday concern in developing countries. When infrastructure fails, it undermines businesses, job creation, and economic development. Population surge and climate change has led to an increase in the frequency and intensity of natural hazards. There is the need to make adaptation and investments in resilience an urgent priority. A resilient infrastructure system should be sufficiently robust, have sufficient redundancy, and allow for sufficient resourcefulness to resolve issues rapidly to continue operating at normal or near normal performance levels. "Infrastructure investments made today are vital as they will not only need to respond to future climate impacts on the infrastructure itself, but will also determine

how its future users live. Climate resilient infrastructure must enable communities and the society mitigate and adapt to climate change impacts" [28,27]. The overlapping and complementary interaction between resilient assets; resilient infrastructure and resilient users (see Fig. 1).

Nofal and van de Lindt [29] observed that "first step to study the resilience of a certain community is the prediction of flood losses. The quantification of flood losses for each community sectors will help define the scope of the recovery process. Flood losses are often classified into direct and indirect flood losses. Direct flood loss refers to the physical damage induced by the event due to objects and their contact with water such as buildings and contents within the inundated area. Indirect losses are derived from the disruptions to businesses, public services, which can lead to business interruption inside and outside the affected area. The flood losses can further be classified into tangible and intangible losses, depending on whether these losses can reasonably be evaluated in monetary terms or not. Tangible losses can be monetized but intangible losses are the damages that cannot be directly assessed in monetary terms. Table 1 presents the classification of the actions that communities may choose to adopt to mitigate flood impacts and speed the recovery process".

Hallegatte et al. [28] noted the following about resilient infrastructure

i. Lack of resilient infrastructure is harmful to people and firms
ii. Investments in more resilient infrastructure is robust, profitable, and urgent
iii. Good infrastructure manageme nt is the bedrock for resilient infrastructure
iv. There is need to define institutional mandates and strategies for infrastructure resilience
v. There is need for the introduction of resilience in the regulations and incentive systems of infrastructure sectors, users, and supply chains
vi. Decision making should be improved through data, tools, and skills
vii. Appropriate financing should be provided – especially for risk-informed master plans, asset design, and preparedness.

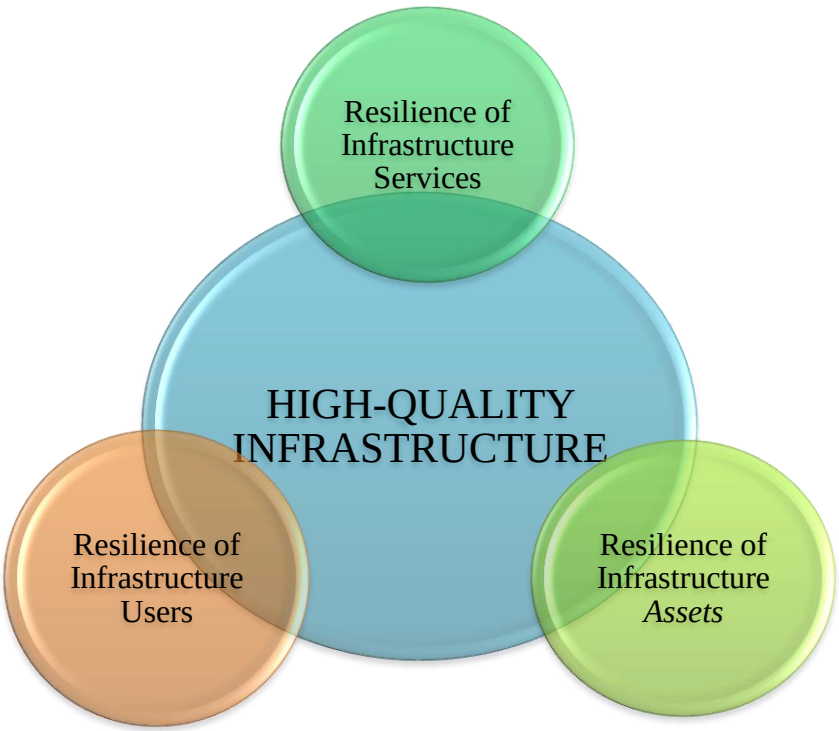

Fig. 1. Interaction between resilient assets; resilient infrastructure and resilient users
(Source: Hallegatte et al., [28])

Table 1. Classification of the actions that communities may choose to adopt to mitigate flood impacts and speed the recovery process

RESILIENT measure	Short-term	Long-term
Pre-disaster	Immediate precautionary measures for community to be implemented after flood warnings: • Construct temporary berms/levees. • Install pumps at critical locations. • Use Sandbags around emergency and critical facilities. • Encourage volunteers to help with filling and moving the sandbags. • Elevate interior building expensive components such as furniture, appliances, and important documents on higher shelves.	Community plans for 100-year flood or any recurrence intervals to protect the buildings located in the floodplain: • Construct permanent berms/levees. • Construct dams, flood exits, flood barriers, floodwalls, and flood gates. • Increase first-floor elevation for the buildings on the floodplain. • Elevate heaters and air conditions. • Reroute ductwork from the crawlspace to the attic.
Post-disaster	Immediate actions for community to be implemented just after the flooding event: • Evacuation Plans. • Temporary shelters. • Secure the food chain. • Provide funds for the impacted buildings. • Encourage voluntary institutions to help with community recovery. • Start Recovery.	New community plans after the lessons learned from past flooding events: • Redesign the flood drainage network based on the lessons learned. • Offer buyout program for the buildings on the floodplain. • Adopt resilient construction methods for new buildings. • Retrofit of the impacted infrastructure to resist future flooding according to the new plans.

Source: Nofal and van de Lindt, [29]

Goal 9 (build resilient infrastructure to promote sustainable industrialization and foster innovation) and Goal 11 (making cities and human settlements inclusive, safe, resilient and sustainable) of the Sustainable Development Goals (SDGs) as established by the United Nations (UN) in 2015 both address infrastructure resilience. Flooding like other hazards threaten the sustainability of cities. There is so much uncertainty and unpredictability about flooding. The need therefore arises for long-term and sustainable FRM measures to be employed in reducing the effect of this menace to its barest minimum, one of which is the implementation of infrastructure resilience. Initial costs of resilient infrastructure most often is high but its long term benefits are enormous. The resilience approach however, requires standard procedures to be formulated to guide its use and implementation. Out of 36 states and the Federal Capital Territory in Nigeria, Lagos State is the only one that has enacted and published the relevant framework for infrastructure resilience. The document Lagos Resilience Strategy [30] was published by the Lagos State Government through the Lagos State Resilience Office (LASRO) in 2020. It is therefore imperative that the government at all levels in Nigeria (federal, state and local) follow that path towed by the Lagos State Government.

5. CONCLUSION

This paper has highlighted the types, causes and impact of floods in Nigeria. Nigeria's Flood Risk Management (FRM) approach – performance and failures were also assessed. It further examined infrastructure resilience and advocates it as a formidable approach for Nigeria's FRM, making recommendations for the possible consideration and implementation of infrastructure resilience in Nigeria. With the annual cycles of flooding in Nigeria and its

devastating consequences, FRM measures such as the resilient infrastructure approach will go a long way in strengthening and reduce the losses associated with flooding to the barest minimum.

6. RECOMMENDATIONS

The following recommendations for practice as suggested below by Oladokun & Proverbs [6] and Hallegatte et al., [28] should be considered and possibly implemented by the Nigerian government.

i. Adoption of an integrated resilient approach to Nigeria's urban infrastructural development and FRM.
ii. A review of ongoing and planned infrastructural projects with a view to optimizing their FRM capabilities while still meeting their intended purposes.
iii. Infrastructure resilience should be built into town planning and development activities; new property developments should strictly be resilient.
iv. Establishment of centre of excellence in Flood Risk Research and Capacity Development to serve as a multidisciplinary platform for generating effective strategic policies and efficient operational mechanisms for FRM in Nigeria.
v. Collaboration between relevant government agencies and professional bodies should be encouraged and strengthened.
vi. Adoption of pragmatic steps toward developing and including suitable FRM concepts and practices into the nation's educational curricula.
vii. Mobilizing and empowering more entrepreneurs into FRM solutions development and service delivery in Nigeria.

Other recommendations (Hallegatte et al., [28] are highlighted in Table 2 (see Appendix 1).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

Table 2. Recommendations to address the obstacles to resilient infrastructure

Recommendation	Actions
Get the basics right	• Introduce and enforce regulations, construction codes, and procurement • rules • Create systems for appropriate infrastructure operation, maintenance, and post-incident response • Provide appropriate funding and financing for infrastructure planning, construction, and maintenance
Build institutions for resilience	• Implement a whole-of-government approach to resilient infrastructure, building on existing regulatory systems • Identify critical infrastructure and define acceptable and intolerable risk levels • Ensure equitable access to resilient infrastructure
Create regulations and incentives for resilience	• Consider resilience objectives in master plans, standards, and regulations and adjust them regularly to account for climate change • Create economic incentives for service providers to offer resilient infrastructure assets and services • Ensure that infrastructure regulations are consistent with risk-informed land use plans and guide development toward safer areas
Improve decision making	• Invest in freely accessible natural hazard and climate change data • Make robust decisions and minimize the potential for regret and • catastrophic failures • Build the skills needed to use data and models and mobilize the know-how of the private sector
Provide financing	• Provide adequate funding to include risk assessments in master plans and early project design • Develop a government-wide financial protection strategy and contingency plans • Promote transparency to better inform investors and decision makers

(Source: Hallegatte et al., [28])

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